Eastern Bottlebrush Grass Yield, Persistence, and Nutritive Value in the Northeastern USA

Matt A. Sanderson,* R. Howard Skinner, Martin van der Grinten, and Jennifer Kujawski

ABSTRACT

Introduced (nonnative) species account for nearly all of the forage grasses used in northeastern USA forage systems. We evaluated accessions of the native cool-season species, Eastern bottlebrush grass (*Elymus hystrix* var. *hystrix* L.), from the northeastern USA for yield, persistence, plant morphological traits, and nutritive value. Thirteen accessions and one commercial ecotype of bottlebrush grass were transplanted into single-row field plots in late summer of 2000 at Beltsville, MD, Rock Springs, PA, and Big Flats, NY. Two orchardgrass (*Dactylis glomerata* L.) cultivars were included for reference. Yield, persistence, morphology (leaf width, length, mass, area, and tillers per plant), and nutritive value data were collected during 2001 and 2002. Bottlebrush grass was eliminated by the bluegrass billbug (*Sphenophorus parvulus* Gyllenhal) at Rock Springs in spring of 2001. At Big Flats and Beltsville, the bottlebrush grass accessions produced as much dry matter per plant as the commercial ecotype. Orchardgrass yielded four times as much dry matter as the mean of all bottlebrush grass entries (102 g vs. 26 g per plant averaged for years and locations). The low productivity of bottlebrush grass resulted from reduced tillering especially during regrowth. There was very little regrowth of bottlebrush grass during late summer in all environments. Survival of bottlebrush grass was 36% during 3 yr vs. 84% for orchardgrass. Differences in nutritive value among accessions were due mainly to differences in leaf-to-stem mass ratio. Eastern bottlebrush grass has limited potential for use as a forage grass in the northeastern USA.

The commonly used cool-season forage grasses in the northeastern USA are introduced species. The native grasses most often used in northeastern forage systems are warm-season perennials such as switchgrass (*Panicum virgatum* L.) and big bluestem (*Andropogon gerardii* Vitman). Interest in the use of native plant species for conservation and production has increased during recent years because of new federal policies related to invasive species, conservation plantings, farm programs, and ecosystem restoration that encourage the use of native plants (Richards et al., 1998; Federal Register, 1999; Booth and Jones, 2001). Almost no information exists on the use of native cool-season grasses as forage species in the northeastern USA.

Eastern bottlebrush grass, a perennial cool-season grass native to the northeastern USA, grows mainly in river valleys and along woodlands (Pohl, 1947; Hitchcock, 1971). A recent review of *Elymus* species did not include any information on bottlebrush grass (Asay and Jensen, 1996). Virginia wildrye (*Elymus virginicus* L.) has been evaluated in the northeastern USA in terms of yield, persistence, and nutritive value (Sanderson et al., 2004a, 2004b). Virginia wildrye performed better on a deep soil in New York compared with shallow or sandy soils in Pennsylvania and Maryland, respectively. The nutritive value of Virginia wildrye was comparable to that of orchardgrass; however, orchardgrass was much more productive and persistent.

There is a need for more information on the usefulness of locally adapted native grasses in production, conservation, and other plantings in the northeastern USA. Therefore, we evaluated several northeastern collections of bottlebrush grass for dry matter yield, persistence, morphological characteristics, and nutritive value at three locations.

MATERIALS AND METHODS

The experiment was conducted at the USDA-NRCS Plant Materials Center in Big Flats, NY (42°N, 76°54′ W, elevation 290 m), the Russell E. Larson Agricultural Research Center at Rock Springs, PA (40°48′ N, 77°52′ W, elevation 365 m), and the USDA-NRCS National Plant Materials Center in Beltsville, MD (39°02′ N, 76°56′ W, elevation 36 m) from 2000 to 2002. Soil types were Unadilla silt loam (coarse-silty, mixed, active, mesic Typic Dystrudepts) at Big Flats, Hagerstown silt loam (fine, mixed, semiactive, mesic, Typic Hapludalfs) at Rock Springs, and Iuka sandy loam (coarse, loamy, siliceous, active, acid, thermic, Aquic Udifluvents) at Beltsville. The site at Big Flats was near the Chemung River and a woodland margin. The Beltsville site was in a similar woodland edge setting, but not in a river valley, and was on a gentle slope (2–5%) with an eastern aspect. The Rock Springs plots were on an upland agricultural site. Weather data (Table 1) were recorded at meteorological stations near each site.

The bottlebrush grass accessions were collected by the USDA-NRCS plant materials centers from several northeastern states in 1998 and 1999 (Table 2). Thirteen accessions and a commercial ecotype (Ernst Conservation Seeds, Meadville, PA) of bottlebrush grass were transplanted into single-row field plots during August 2000 at Rock Springs and Big Flats and September 2000 at Beltsville. Two orchardgrass cultivars (Potomac and Pennlate) were included for reference only. Each entry was established from seed in the greenhouse at the National Plant Materials Center, Beltsville. Entries were hand transplanted into single-row plots of 10 plants per plot. Each plot of 10 plants contained eight experimental plants and a border plant of the commercial ecotype at each end of the row. Border rows of the commercial ecotype alternated with row plots of the accessions. Plants were spaced 30 cm apart within rows, and rows were spaced 30 cm apart. At each location, a plastic weed barrier controlled weeds during establishment. The plastic weed barrier was removed from all

Matt A. Sanderson and R. Howard Skinner, USDA-ARS Pasture Systems and Watershed Management Research Unit, Bldg. 3702, Curtin Road, University Park, PA 16802-3702; Martin van der Grinten, USDA-NRCS Plant Materials Center, Big Flats, NY 14830; Jennifer Kujawski, USDA-NRCS. Received 18 Feb. 2004. *Corresponding author (mas44@psu.edu).

Published in Crop Sci. 44:2193–2198 (2004).

677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: CP, crude protein; dNDF, digestible neutral detergent fiber; IVTD, in vitro true digestibility; LSR, leaf-to-stem mass ratio; NDF, neutral detergent fiber; SLA, specific leaf area.

Table 1. Monthly average air temperature and total rainfall at Big Flats, NY, and Beltsville, MD, during 2001 and 2002 compared with the 30-yr average (1961–1990).

	Big Flats, NY			Beltsville, MD		
Month	2001	2002	30-yr average	2001	2002	30-yr average
			Air temperature, °C			
March	3.0	2.8	0.9	4.8	7.3	6.0
April	12.1	9.2	7.6	12.6	13.6	11.2
May	8.1	12.4	13.0	16.8	16.6	16.7
June	20.2	20.0	18.0	22.4	22.4	21.7
July	20.4	23.1	20.9	22.1	24.9	24.2
August	22.7	22.8	19.9	23.8	24.3	23.4
September	16.3	19.0	15.9	17.7	20.0	19.6
			Rainfall, mm			
March	96	57	66	85	77	84
April	18	64	71	33	90	84
May	58	122	82	114	61	109
June	51	145	84	137	59	89
July	25	14	82	127	69	104
August	41	28	77	128	84	104
September	94	70	79	55	75	94

plots in March (Beltsville) or April 2001 (Big Flats and Rock Springs) after which weeds were controlled by hand and with herbicides.

Soil pH (to a 15-cm depth) was 5.7 at Big Flats, 6.5 at Rock Springs, and 6.1 at Beltsville. Soil P (114–254 kg ha^{-1}) was above optimum at each location, whereas soil K (134–260 kg ha^{-1}) was below optimum at two sites. Potassium fertilizer (0-0-60) was applied at 40 kg K ha^{-1} at each location in April 2001. Nitrogen (as ammonium nitrate) was applied at 56 kg ha^{-1} at green-up in the spring (late March or early April) and after the second harvest each year.

Plots were harvested in April and June at Beltsville and in May and July at Big Flats in 2001 and 2002. Bottlebrush grass survival was poor at Rock Springs and the site was abandoned in spring of 2001. In 2001 and 2002, late summer and fall regrowth at each location was limited and it was decided not to take a third harvest. Bottlebrush grass accessions were at the late vegetative developmental stage at all harvests. Orchardgrass was at the inflorescence emergence stage at the first harvest and was vegetative at the second harvest. At each harvest, the number of tillers was counted on the first two experimental plants in each row. The last two experimental plants in each row were not clipped at the first harvest in each year but were monitored for anthesis date and then clipped after anthesis was reached. The same two plants were monitored each year. The remaining six experimental plants in each row were clipped to a 7-cm height, placed in cloth bags, and dried at 55°C for 48 h to determine dry matter yield per plant and for nutritive value analysis. The plot was discarded for yield purposes if fewer than four of the six plants were alive. The number of surviving experimental plants of each accession was counted in May 2003 at each location to assess persistence.

At the first harvest each year, 10 tillers of similar morphological developmental stage were taken from the experimental plants in each row. The number of leaves was counted on each tiller and the length and width of the three youngest fully elongated leaf blades were measured and leaf area calculated with a laser area meter (CID model CI-203, CID Devices Inc., Vancouver, WA). After measurements, the leaf blades and stems (including the leaf sheath) were dried at 55°C for 48 h, weighed, and the leaf-to-stem mass ratio (LSR) and specific leaf area (SLA, cm^2 leaf area g^{-1} leaf mass) were calculated.

Forage samples from the first harvest at each location were analyzed for nutritive value via calibrated near infrared reflectance spectroscopy by the Crop Quality Laboratory at the Pennsylvania State University. Calibration samples were analyzed for neutral detergent fiber (NDF), in vitro true digestibility (IVTD; 48-h fermentation), and crude protein (CP) by a commercial laboratory (DairyOne, Ithaca, NY). Detergent fiber and IVTD procedures were according to Van Soest and Robertson (1980). Digestible NDF (dNDF) was calculated from NDF and IVTD values. Nitrogen was determined by the Dumas combustion method (AOAC, 1990) and CP calculated as N $\times$ 6.25. Calibration statistics were CP, standard error of prediction corrected for bias [SEP(C)], 7.4; R^2, 0.99; NDF, SEP(C), 8.8; R^2, 0.88; IVTD, SEP(C), 15.7; R^2, 0.88.

The experiment was a randomized complete block design with four blocks at each location. Plot means were used in the analysis of variance. Data were analyzed and expressed on a per plant basis to simplify presentation and compensate for missing plants. Yield data were the total of two harvests in each year. A combined analysis across years and locations was done on all data. Years and locations were considered random effects and the accessions were considered fixed effects. The MIXED procedure in SAS (Littell et al., 1996) was used to perform the analysis. Denominator degrees of freedom were calculated using the Satterthwaite option of MIXED analysis to determine appropriate degrees of freedom to test fixed effects and interactions of fixed effects. Planned contrasts were used to compare means. The contrasts were (i) average of bottlebrush grass entries vs. average of orchardgrass cultivars; (ii) average of Ontario, Pennsylvania, New York, Vermont, and New Hampshire accessions vs. average of Maryland, West Virginia, and Washington, DC, accessions (northern vs. southern accessions); and (iii) average of all accessions vs. the commercial ecotype. Pearson's product moment correlations were used to determine associations between nutritive value and plant morphological traits (leaf area, length, width, SLA, and LSR). Statistical significance was declared at the $P <$ 0.05 level.

Table 2. Origin of bottlebrush grass accessions evaluated.

Accession	Origin	Date collected
9051823	Ontario, Canada	September 1998
9051827	Ontario, Canada	August 1998
9080130	Washington, DC	September 1999
9080131	Washington County, MD	July 1997
9085126	Washington County, MD	August 1998
9085140	Montgomery County, MD	September 1998
9085157	Frederick County, MD	September 1998
9051825	Cheshire County, NH	August 1998
9051829	Tioga County, NY	September 1999
9051824	Bennington County, VT	August 1998
9080166	Jefferson County, WV	August 1998
9085135	Jefferson County, WV	August 1998
9085161	Crawford County, PA	
Commercial ecotype	Crawford County, PA	

RESULTS AND DISCUSSION

In Pennsylvania, bottlebrush grass performed poorly and did not survive after the first harvest in 2001. We examined several plants and found that they were infested by the bluegrass billbug, which feeds on roots and growing points. We did not observe billbug injury on bottlebrush grass at Beltsville or Big Flats. Other species of *Elymus* also have been identified as very susceptible to billbugs (Asay et al., 1983).

The combined statistical analysis indicated interactions among years, locations, and accessions for yield, plant morphology, and nutritive value; therefore, data are presented by year and location. Variation between years and sites was probably due to weather conditions. In 2001, rainfall for April to August was well below the long-term average at Big Flats (Table 1). Rainfall was adequate for most of the 2001 growing season at Beltsville; however, rainfall from September 2001 continuing through 2002 was much below the long-term average. In 2002, May and June rainfall was well above the long-term average at Big Flats, whereas July and August rainfall was much below average and summer temperatures were above average.

The average date of anthesis for the bottlebrush grass accessions and cultivars during the 2 yr was the second week of June at Beltsville and the first week of July at Big Flats (data not shown). Anthesis date for orchardgrass was 4 to 6 wk earlier than bottlebrush grass.

Dry Matter Yield per Plant and Persistence

Yield did not differ between the average of the northern or southern entries and the average of the accessions versus the commercial ecotype at Big Flats in both years (Table 3). The West Virginia accessions diverged widely in yield in 2002 at Big Flats and the Pennsylvania accession and commercial ecotype appeared to be much lower in yield than most other accessions in 2002. At Beltsville, the northern accessions yielded less than the southern accessions in 2002. The commercial ecotype yielded more than the average of the accessions only at Beltsville in 2001. At both locations the bottlebrush grass entries had very little regrowth in late summer and fall of 2001 and 2002. Orchardgrass yielded more dry matter per plant than bottlebrush grass at each location and in each year. Orchardgrass was included only as a frame of reference. The bottlebrush grass accessions have had no selection or breeding, whereas the orchardgrasses are proven cultivars from breeding programs.

The bottlebrush grass accessions differed in persistence (Table 3). The southern accessions had better survival on average than the accessions from northern states. At Beltsville, accession 9051824 from Vermont and 9051825 from New Hampshire had the poorest survival. Overall, bottlebrush grass survival was lower than that of orchardgrass. The severe drought in 2002 coupled with sandy soil at Beltsville caused significant plant death in both bottlebrush grass and orchardgrass.

The field sites at Big Flats and Beltsville were representative of the natural habitat of bottlebrush grass, with the exception of a woodland canopy. The relatively cool, wet climate along with a deep soil with a good water holding capacity at Big Flats would seem to be conducive to bottlebrush grass growth. It did not appear, however, that bottlebrush grass persisted better at Big Flats than at Beltsville. Both experimental sites were open; perhaps performance would have been different under a woody canopy, such as in a silvopastoral system.

In a similar study, we found that Virginia wildrye also had much lower yield than orchardgrass (Sanderson et al., 2004a). Virginia wildrye averaged 42 g of dry matter

Table 3. Dry matter yield and survival of bottlebrush grass and orchardgrass at Big Flats, NY, and Beltsville, MD. Yield data are the sum of two harvests in each year and least squares means of four replicates. Survival data are the percentage of original plants alive in May of 2003.

		Dry matter yield					
		Big Flats		Beltsville		Survival	
Accession	Origin	2001	2002	2001	2002	Big Flats	Beltsville
		g dry matter plant^{-1}				%	
9080166	WV	46	19	20	20	44	44
9085135	WV	26	51	29	28	28	50
9080130	DC	41	29	32	26	41	55
9080131	MD	38	25	28	9	56	41
9085126	MD	45	21	31	13	50	47
9085140	MD	35	18	26	17	34	34
9085157	MD	32	28	27	24	34	67
Southern mean		38	27	28	20	41	48
9051823	Ontario	35	31	19	8	22	34
9051827	Ontario	37	25	18	10	31	25
9051825	NH	41	34	24	10	25	9
9051829	NY	45	32	27	12	53	22
9051824	VT	57	28	28	7	25	9
9085161	PA	42	18	28	17	19	28
Commercial ecotype	PA	43	16	37	16	34	50
Northern mean		43	26	26	11	30	25
Bottlebrush mean		41	26	27	16	35	36
Orchardgrass mean		102	203	52	54	98	70
SE		5.4	6.9	3.4	4.4–9.1	10.0	12.2
Contrasts†							
Bottlebrush vs. OG		**	**	**	**	**	**
North vs. South		NS	NS	NS	**	*	**
Accession vs. ecotype		NS	NS	**	NS	NS	NS

* Significant at $P < 0.05$.
** Significant at $P < 0.01$
NS, not significant.
† Contrasts were: Bottlebrush vs. OG, average of bottlebrush entries vs. average of orchardgrass cultivars; North vs. South, average of Ontario, Pennsylvania, New York, Vermont, and New Hampshire accessions vs. average of Maryland, West Virginia, and Washington, DC accessions; Accession vs. ecotype, average of all accessions vs. commercial ecotype.

Table 4. Number of tillers per plant of bottlebrush grass and orchardgrass at two harvests (H1 and H2) during 2 yr at Big Flats, NY, and Beltsville, MD. Data are least squares means of four replicates.

	Big Flats, NY				Beltsville, MD			
	2001		2002		2001		2002	
Accession or cultivar	H1	H2	H1	H2	H1	H2	H1	H2
Commercial ecotype	57	7	38	13	76	36	35	26
Southern accession mean	55	15	57	23	68	30	38	27
Northern accession mean	48	9	53	17	56	23	25	20
Bottlebrush mean	52	12	55	20	62	26	32	24
Orchardgrass mean	108	148	178	172	58	100	121	101
SE	5.9	10.9	11.9	7.3–10.4	7.3	6.7	9.4	4.8–10.0
Contrasts†								
Bottlebrush vs. OG	**	**	**	**	NS	**	**	**
North vs. South	*	NS	NS	NS	**	NS	*	NS
Accession vs. ecotype	NS	NS	NS	NS	NS	NS	NS	NS

* Significant at $P < 0.05$.
** Significant at $P < 0.01$
NS, not significant.
† Contrasts were: Bottlebrush vs. OG, average of bottlebrush entries vs. average of orchardgrass cultivars; North vs. South, average of Ontario, Pennsylvania, New York, Vermont, and New Hampshire accessions vs. average of Maryland, West Virginia, and Washington, DC, accessions; Accession vs. ecotype, average of all accessions vs. commercial ecotype.

per plant at Big Flats and 29 g of dry matter per plant at Beltsville for 2 yr. Survival of Virginia wildrye at Big Flats was 66 and 46% at Beltsville. Thus, bottlebrush grass was not as productive or persistent as Virginia wildrye in the northeastern USA.

Plant Morphology

Tillers per Plant

Among the bottlebrush grass entries, the southern accessions produced more tillers per plant at the first harvest each year at Beltsville and at the first harvest in 2001 at Big Flats (Table 4). With one exception (Harvest 1 in 2001 at Beltsville), orchardgrass produced more tillers per plant than bottlebrush grass.

Bottlebrush grass seemed to have a very limited ability to maintain or activate axillary tillers after clipping. Accessions of bottlebrush grass had few tillers at Harvest 2 compared with Harvest 1, whereas orchardgrass maintained or increased tiller numbers between harvests (Table 4). It appeared that bottlebrush grass tillers tended to be synchronous in development and most tillers had elevated the growing point before harvest, whereas orchardgrass maintained more unelongated, vegetative tillers. We observed a similar tillering pattern for Virginia wildrye (Sanderson et al., 2004a). Tillers with elevated growing points must be replaced by new tillers from axillary meristems, whereas vegetative tillers continue to grow after clipping. Sometimes clipping reproductive tillers stimulates axillary tiller growth (Olson and Richards, 1988; Richards et al., 1988); however, regrowth from axillary tillers is slower than regrowth from intercalary or leaf primordial meristems (Briske, 1986).

The lack of defoliation resistance mechanisms (e.g., a prostrate growth habit, asynchronous tiller development, and compensatory physiological processes; Briske, 1986), the lack of vigorous regrowth, and the existing growth habit of bottlebrush grass and Virginia wildrye suggests that defoliation was not a selection pressure in the evolution of these accessions. Thus, developing forage types of these native grasses would require substantially altering their growth habit and tillering mechanisms.

Leaf Blade Traits

Bottlebrush grass leaf blades differed from orchardgrass in several leaf blade traits. Leaf blades of bottlebrush grass were shorter, wider, and higher in SLA than orchardgrass (Table 5). The bottlebrush grass accessions also had a greater LSR than orchardgrass. The southern accessions had longer and narrower leaves with a greater SLA than the accessions from more northern states. The LSR of the southern accessions was significantly greater at Big Flats but not at Beltsville. There were few differences between the average of the accessions and the commercial ecotype in leaf blade traits.

Nutritive Value

Bottlebrush grass accessions and orchardgrass differed significantly in nutritive value constituents (Table 6). On average, bottlebrush grass had greater CP, lower NDF, and greater dNDF than the orchardgrass cultivars at both Big Flats and Beltsville. This was probably because bottlebrush grass was less mature (late vegetative stage) than orchardgrass (inflorescence emergence) at harvest. The southern accessions had greater CP, lower NDF, and higher dNDF than northern accessions at Big Flats. The commercial ecotype had lower NDF and greater dNDF than the average of the accessions at Beltsville and the northern and southern accessions differed only in CP. Nutritive value constituents in *Elymus* and orchardgrass were greater at Beltsville than at Big Flats because of the earlier harvest date at Beltsville.

Although the grass entries differed in nutritive value constituents, most of the variation may have been caused by differences in LSR. Concentrations of CP and dNDF were positively correlated with LSR ($r = 0.64$ and 0.57, respectively; $P < 0.01$), whereas NDF concentrations were negatively correlated ($r = -0.42$; $P <$

Table 5. Leaf morphology of bottlebrush grass and orchardgrass at Big Flats, NY, and Beltsville, MD. Data are least squares means of four replicates and 2 yr.

	Area		Length		Width		Specific leaf area		Leaf-to-stem ratio	
Accession or cultivar	Big Flats	Beltsville	Big Flats	Beltsville	Big Flats	Beltsville	Big Flats	Beltsville	Big Flats	Beltsville
	— cm^2 $leaf^{-1}$ —		— cm $leaf^{-1}$ —				— cm^2 g^{-1} leaf DM —			
Commercial ecotype	17.7	16.9	17.0	15.9	1.42	1.46	321	283	0.69	1.68
Southern accession mean	16.3	15.9	18.9	17.4	1.20	1.19	336	290	0.84	1.52
Northern accession mean	17.4	17.4	16.8	16.4	1.38	1.46	311	271	0.71	1.50
Bottlebrush grass mean	16.8	16.6	17.8	16.9	1.30	1.32	324	281	0.78	1.51
Orchardgrass mean	16.2	21.2	24.9	26.7	0.88	1.14	306	263	0.52	1.10
SE	1.24	1.11	0.96	1.24	0.065	0.047	11.9	7.2	0.047	0.227
Contrasts†										
BBG. vs. OG	NS	**	**	**	**	**	NS	**	**	**
North vs. South	NS	**	**	**	**	**	**	**	**	NS
Accession vs. ecotype	NS	NS	NS	NS	*	**	NS	NS	*	NS

* Significant at $P < 0.05$.
** Significant at $P < 0.01$
NS, not significant.
† Contrasts were: BBG. vs. OG, average of bottlebrush entries vs. average of orchardgrass cultivars; North vs. South, average of Ontario, Pennsylvania, New York, Vermont, and New Hampshire accessions vs. average of Maryland, West Virginia, and Washington, DC, accessions; Accession vs. ecotype, average of all accessions vs. commercial ecotype.

0.01). These correlations are consistent with results from a similar evaluation of Virginia wildrye (Sanderson et al., 2004b). Weak or inconsistent correlations occurred with leaf area, length, width, and specific leaf area (data not shown). Grass leaves generally are lower in fiber and higher in digestibility than stems, thus a greater LSR should result in greater nutritive value (Hacker and Minson, 1981). In other forage crops, such as alfalfa (*Medicago sativa* L.), selection for improved nutritive value altered LSR (Kephart et al., 1989).

CONCLUSIONS

Our results from 2 yr and three locations show that Eastern bottlebrush grass has limited potential for use as a forage grass in the northeastern USA because of its lack of defoliation tolerance, limited regrowth, and poor persistence. It may be more suited to other uses such as native grassland restoration or as part of conservation planting mixtures where defoliation does not occur. Because of its native adaptation to woodland margins, perhaps bottlebrush grass would persist and perform

Table 6. Nutritive value of bottlebrush grass and orchardgrass at Big Flats, NY, and Beltsville, MD. Data are least squares means of four replicates and 2 yr.

		Big Flats, NY			Beltsville, MD		
Accession or cultivar	Origin	CP†	NDF	dNDF	CP	NDF	dNDF
		– g kg^{-1} dry matter –		g kg^{-1} NDF	– g kg^{-1} dry matter –		g kg^{-1} NDF
9080166	WV	188	464	665	239	422	771
9085135	WV	220	450	712	293	368	850
9080130	DC	184	492	658	258	411	804
9080131	MD	191	467	680	266	414	799
9085126	MD	176	475	650	245	441	745
9085140	MD	193	468	688	240	443	752
9085157	MD	210	451	691	264	411	793
Southern mean		195	467	678	258	416	788
9051823	Ontario	162	481	624	244	399	796
9051827	Ontario	154	482	631	225	420	771
9051825	NH	182	475	653	261	414	795
9051829	NY	153	478	648	228	430	779
9051824	VT	156	511	623	227	440	746
9085161	PA	178	467	690	247	394	828
Commercial ecotype	PA	174	465	673	252	399	819
Northern mean		166	480	649	241	414	791
Bottlebrush mean		181	474	664	250	415	790
Orchardgrass mean		148	616	652	247	478	769
SE		4.9	6.0	7.4	7.0	8.8	11.7
Contrasts‡							
Bottlebrush vs. OG		**	**	*	NS	**	**
North vs. South		**	**	**	**	NS	NS
Accession vs. ecotype		NS	NS	NS	NS	*	**

* Significant at $P < 0.05$.
** Significant at $P < 0.01$
NS, not significant.
† CP, crude protein; NDF, neutral detergent fiber; dNDF, digestible neutral detergent fiber.
‡ Contrasts were: Bottlebrush vs. OG, average of bottlebrush entries vs. average of orchardgrass cultivars; North vs. South, average of Ontario, Pennsylvania, New York, Vermont, and New Hampshire accessions vs. average of Maryland, West Virginia, and Washington, DC, accessions; Accession vs. ecotype, average of all accessions vs. commercial ecotype.

better in a silvopastoral system. Bottlebrush grass appears to be sensitive to drought and should not be used on soils with low water-holding capacity or where bluegrass billbug may be abundant.

REFERENCES

Asay, K.H., J.D. Hansen, B.A. Haws, and P.O. Currie. 1983. Genetic differences in resistance of range grasses to the bluegrass billbug, *Sphenoporus parvulus* (Coleoptera:Curculionidae). J. Range Manage. 36:771–772.

Asay, K.H., and K.B. Jensen. 1996. Wildryes. p. 725–745. *In* L.E. Moser et al. (ed.) Cool-season forage grasses. Agron. Monogr. 34. ASA, CSSA, and SSSA, Madison, WI.

Association of Official Analytical Chemists. 1990. Method 990.03, Crude protein in animal feed. Official methods of analysis. 19th ed. AOAC, Arlington, VA.

Booth, D.T., and T.A. Jones. 2001. Plants for ecological restoration: A foundation for the future. Native Plants J. 2:12–20.

Briske, D.D. 1986. Plant response to defoliation: Morphological considerations and allocation priorities. p. 425–427. *In* P.J. Joss et al. (ed.) Rangelands: A resource under siege. Cambridge Univ. Press, New York.

Federal Register. 1999. Executive order 13112. Invasive species. Fed. Regist. 64(25):6183–6186.

Hacker, J.B., and D.J. Minson. 1981. The digestibility of plant parts. Herb. Abstr. 51:459–482.

Hitchcock, A.S. 1971. Manual of the grasses of the United States. 2nd ed. (revised by A. Chase) Dover Publ., Inc., New York.

Kephart, K.D., D.R. Buxton, and R.R. Hill, Jr. 1989. Morphology of alfalfa selected for herbage lignin concentrations. Crop Sci. 29: 778–782.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Inst. Inc., Cary, NC.

Olson, B.E., and J.H. Richards. 1988. Tussock regrowth after grazing: Intercalary meristem and axillary bud activity of tillers of *Agropyron desertorum*. Oikos 51:374–382.

Pohl, R.W. 1947. A taxonomic study on the grasses of Pennsylvania. Am. Midl. Nat. 38:513–604.

Richards, J.H., R.J. Mueller, and J.J. Mott. 1988. Tillering in tussock grasses in relation to defoliation and apical bud removal. Ann. Bot. 62:173–179.

Richards, R.T., J.C. Chambers, and C. Ross. 1998. Use of native plants on federal lands: Policy and practice. J. Range Manage. 51:625–632.

Sanderson, M.A., R.H. Skinner, J. Kujawski, and M. van der Grinten. 2004a. Virginia wildrye evaluated as a potential native cool-season forage in the Northeast USA. Crop Sci. 44:1379–1384.

Sanderson, M.A., R.H. Skinner, J. Kujawski, and M. van der Grinten. 2004b. Nutritive value of Virginia wildrye, a cool-season grass native to the Northeast USA. Crop Sci. 44:1385–1390.

Van Soest, P.J., and J.B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. p. 49–60. *In* W.J. Pigden et al. (ed.) Standardization of analytical methodology for feeds: Proc. Int. Workshop, Ottawa, ON. 12–14 Mar. 1979. Rep. IRDC-134e. Int. Dev. Res. Ctr., Ottawa, ON, Canada and Unipub, New York.